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EFFECT OF ELECTROLESS NICKEL (EN) COATING ON MECHANICAL PROPERTIES OF Al-6061

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Original Article

ABSTRACT

Al-6061 and Nickel, individually serve for various requirements of their multitude mechanical characteristics and ideal chemical properties. In present scenario, Al-6061 has captured the attention of both academia and industrialists' interest for its usage in multiple fields such as transportation, construction and similar engineering industries. The primary intention of this research is to investigate the properties of mechanical strength ofAl-6061 subjected to Electroless Nickel (EN) coating. The test specimens are prepared as per ASTM norms, and have been evaluated by the addition of EN coating layers of thicknesses 0μ, 2μ, 4μ, 6μ and 8μ. The EN coated specimens are tested for investigating various mechanical properties. These investigations are performed as per ASTM standards. The results thus obtained reveal that, the properties of mechanical strength, such as elastic strength and UTS increases up to 6μ thickness of EN coated specimen. The characteristics viz. hardness and impact energy absorption of a material increases with higher EN coating layer thickness. It has been observed that there is improvement in the properties of Al-6061 coated with EN when compared to the other coated materials as well as non-coated Al-6061. The EN coated Al-6061finds its broad applications in the field of structural and defence/aviation sectors.

KEYWORDS: Electroless Nickel Coating & Al-6061

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1. INTRODUCTION

In this era of rapid development of cosmopolitan advancements, materials with unmatched higher quality levels that can compete with the existing/traditionally used metal alloy(s), ceramic (s) and polymer(s) are the need of hour [7,12]. Materials possessing high strength are comparatively denser, and an increase in the strength / stiffness in these materials will result in the descending impact strength [13]. Further, present day situations demand for less use of material with increased property combinations, for the most economical and productive output[9]. These factors have propelled modern designers to develop these composite materials for a variety of outcomes, based on requirements.

Aluminium is known for its wide usage as a material for matrix in MMC's. Al alloy(s) grab attraction for their known properties viz. lower/reduced density, high strength over weight ratio, good corrosion resistance, high thermal conductivity, electrical conductivity and high damping capacity [8]. MMC's with Al as base metal are being broadly used in many industries, as they fetch a huge classification of properties of mechanical strength, with respect to the chemical configuration of the aluminium MMC's. Experiments have shown that the concentration of Al-6061 combinations enhance alongside the increase of SiC weight fraction, thus abiding the composite mixture rules. Further, hardness values and UTS of Al-6061/SiC composite materials were increased with SiC composition

in the matrix [1]. Al-6061-TiO_2 composite envisioned higher wear resisting capacityoverAl-6061 matrix, and the composite that housed larger filler composition obtained displayed the ever longing properties of mechanical strength and wear resistance capabilities [2]. Attempts have been made to show that the better properties such mechanical strength and fracture toughness can be achieved through EN coating on Al-7075, subjected to T6 treatment [3]. Experimental characterization of electroplated cadmium coating of Al -Zn alloy subjected to T6 treatment have envisioned enhanced properties of mechanical strength and fracture toughness [4]. Better corrosion resistance is achieved by Al-7075 metal matrix composites through Stir casting technique [5]. Experiments have been carried out to bring out the effect of casting mold on both properties of mechanical strength and wear resistance capabilities of Al-6061 [6]. Impact strength and compressive strength were found to be enhanced with the addition of flyash particles to Al-6061 alloy [10]. Al-6061 was studied for its properties of mechanical strength and microstructure at room temperature, after subjecting the specimens to various increased temperatures in a controlled environment at varied rate of heating and natural cooling to room temperature [11]. The synthesis of Al-6061-Glass particulate composite was obtained through the stir casting method, the result of which is the considerable increase in the mechanical properties of the composite [14].

Present work involves EN coating, a chemical reaction that adsorbs a uniform film of nickel on the surface of a solid material. EN coating involves sinking Al-6061materialin a pool of coating agent along with a reducing agent that reacts with the ions of Al-6061 and form a thin film of nickel (in microns), on the surface of Al-6061[3]. EN coating is used in the applications that demand high wear resistance, hardness and corrosion resistance.

2. METHODOLOGY

2.1 EN Coating and Experimentation

In the current work, an attempt is being made to study the mechanical properties of the Al-6061material subjected to EN Coating. The specimens are coated with varied thickness ranging from 2µ to 8µ (viz. 2µ,4µ, 6µ and 8µ). The thickness of the layer on the test specimen depends upon the time of EN dipping and the temperature at which the dipping is carried out. Samples of ASTM standard sizes are then prepared for the testing of specimens for its tensile strength, impact strength, and micro-hardness. Further, the specimens of varied thicknesses of EN coating are subjected to micro-structural observations.

3. RESULTS AND DISCUSSIONS

3.1 Tensile Test

Tensile test was conducted on the specimen, machined according to the ASTM E8-15a. Results are tabulated in the table 3.1 and different graphs viz. elastic strength and UTS against different microns of coated specimen are plotted.

Table 3.1: Tensile Test Results

Composition	0µ	2µ	4µ	6µ	8µ
Yield Strength (MPa)	143.5	201	205	211	189
Ultimate Tensile Strength (MPa)	146.65	236	248	259	225

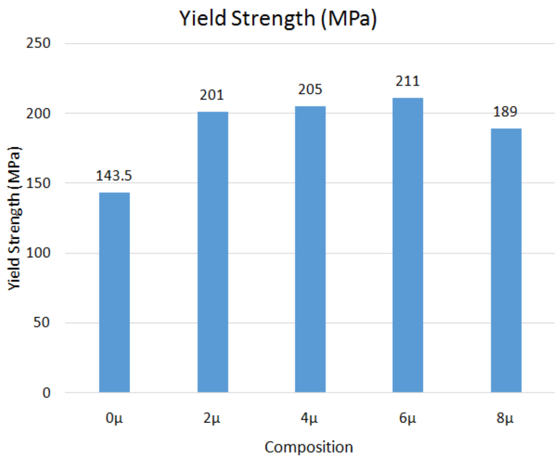

Figure 3.1: Yield Strength vs Thickness of EN Coating

From the figure 3.1, it is evident that the Yield Strength of the nickel coated Al-6061 increases upto 6μ coated specimen and then decreases. The minimum and maximum yield strength can be observed against 0μ (143.45 MPa) and 6μ (211 MPa) thick EN coated specimens. It can be concluded that the EN coating has considerable effect on Al-6061, which results in increased yield strength values upto 6μ. There is a significant decrease in the tensile strength for 8μ (189 MPa), and this decrease can be attributed to the agglomeration phenomenon, where the effect of EN coating on yield strength gradually reduces with further increase in the EN coating.

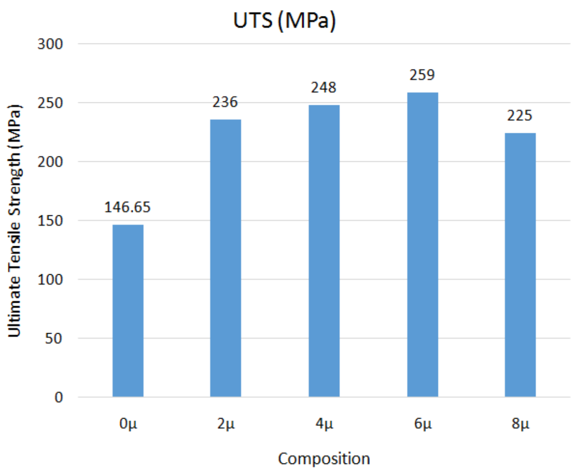

Figure 3.2: UTS vs Thickness of EN Coating

It can be seen from the figure 3.2 that, the Ultimate Tensile Strength (UTS) of the nickel coated Al-6061follows the same trend as that of the yield strength values, as shown in figure 3.1. Further, the cause for this behavior of the material can be attributed similar to that of the behavior of the material in its yield strength. The minimum and maximum UTS are obtained against 0μ (146.65 MPa) and 6μ (259 MPa) thick EN coated specimens.

3.2 Impact Test

Al-6061 specimens rupture at the junction of the notch due to impact caused by the swinging hammer, and thus the energy (impact strength) absorbed in this process is determined. The Impact strength absorbed is tabulated in the table 3.2 and the graph of Impact Load vs composition is plotted.

Table 3.2: Impact Test Results

Composition	0µ	2µ	4µ	6µ	8µ
Impact Load (J)	7	10	12	17	21

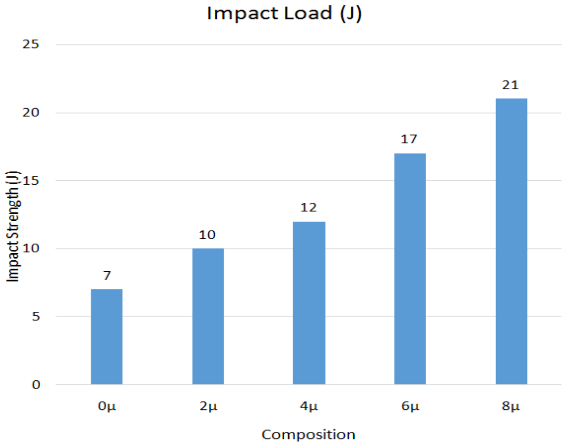

Figure 3.3: Impact Strength vs Thickness of EN Coating

From the figure 3.3, it is evident that the Impact Strength of the nickel coated Al-6061tend to yield higher values with higher thickness of coating layer. It can be inferred through the figure 3.3 that the EN coated Al-6061 specimens will have Impact strength values, which are directly proportional to the thickness of coating layer. The minimum and maximum Impact Strengths are obtained against 0µ (7J) and 8µ (21J) thick EN coated specimens.

3.3 Micro-Hardness Test

The Vicker's hardness test was performed, in accordance with the IS 1501-2011 standard at room temperature condition. Al-6061 coated with EN of 0µ, 2µ, 4µ, 6µand 8µ thicknesses are tested for its micro-hardness, and the results are recorded accordingly. The table3.3 depicts the increase in the hardness values of the EN coated Al-6061 with the rise in the amount of coating.

Table 3.3: Micro-Hardness Test Results

Composition	0µ	2µ	4µ	6µ	8µ
VHN	94	85.8	96.8	90.6	107

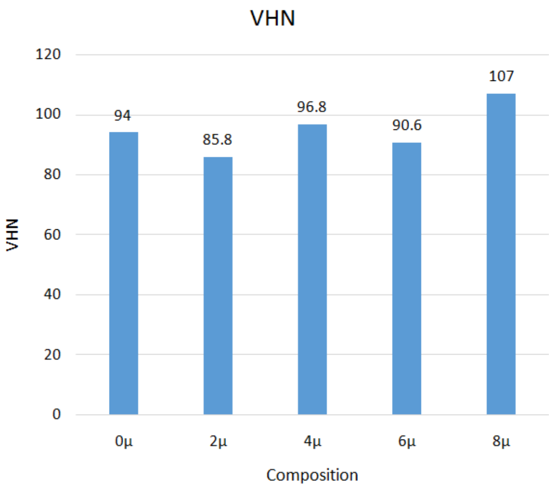

Figure 3.4: VHN vs. Thickness of EN Coating

Figure 3.4 shows that, the Hardness of the EN coated Al-6061 is the highest for 8µ coated specimen amongst all the coating layer thickness. It can therefore be inferred that, the hardness values tend to dominate with the higher thickness of coating layer on Al-6061. The minimum and maximum hardness values are obtained against 2µ (85.5 VHN) and 8µ (107 VHN) thick EN coated specimens.

3.4 Micro Structural Observations

The EN coated Al-6061samples are subjected to micro structural observations, according to IS 7739(P-5)1976 test method through a high resolution optical microscope. The sample is roughened with belt polish and fine polished using emery papers and Lavigated Alimina to enable micro structural surface texture of the EN coated Al-6061. Magnifications of 100X and 5% Nital etchant is used.

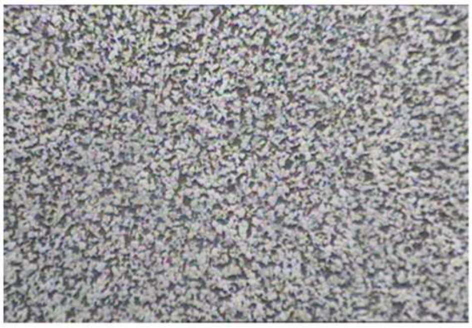

Figure 3.5 (a): Al-6061 with 0µ Coating

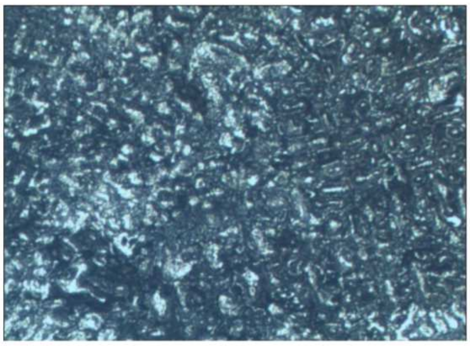

Figure 3.5 (b): Al-6061 with 2µ Coating

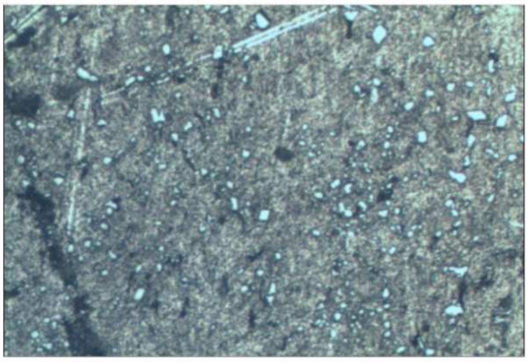

Figure 3.5(c): Al-6061 with 4µ Coating

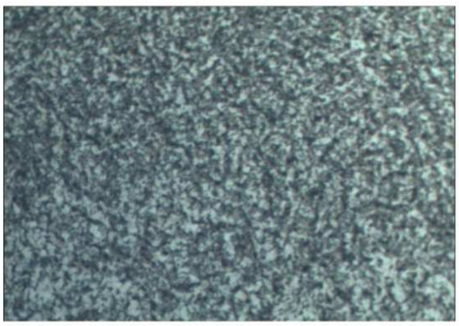

Figure 3.5 (d): Al-6061 with 6µ Coating

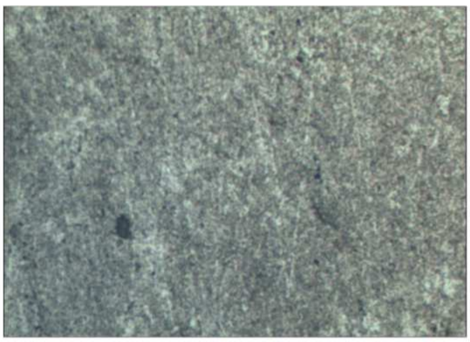

Figure 3.5 (e): Al-6061 with 8µ Coating

Figures 3.5(a) to 3.5(e) show the micro structural morphology of Al-6061, subjected to varying EN coating thickness. It can be observed from the figures that, the 2μ EN coated specimen forms a very thin layer on the base metal surface. The traces of the base metal can be evidently seen in figure 3.5(b). Further, the traces of the base gradually reduce as the thickness of the EN coating is increased. Figure 3.5(e) shows the 8μ thick layer formed on the base metal, where the traces of base metal are hardly visible. This can be attributed to the increase of hardness and the impact strength values, with the increase in EN coating.

CONCLUSIONS

- The EN plating gives high and uniform layer of coating over electroplating.
- It is evident that, the % elongation increases with the increase of EN coating.
- The ultimate tensile strength and yield strength are found to be considerably increased with the increase in EN coating (2μ to 6μ) and decreases thereafter (>6μ i. e. 8μ), thus making it suitable for various structural applications.
- Further, the impact strength is found to have an increasing trend with the thickness of nickel coating, thereby making it very useful in defense /aviation applications.
- The hardness value of an 8μ coated specimens are found to be higher over other samples being tested. Thus, concluding that the hardness increases with increase of EN coating.

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